

LIGHT RESPONSE BY FRANKLINIELLA OCCIDENTALIS TO WHITE FLUORESCENT LIGHT FILTERED THROUGH COLOR FILMS AND ULTRAVIOLET- AND BLUE LIGHT-EMMITING DIODES

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ABSTRACT

Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), are economic pests worldwide. A study was conducted to obtain efficacy data to help develop traps for monitoring WFT population variations in the field and greenhouses. Spectral responses were determined using blue sticky card (BC) traps equipped with light-emitting diodes (LEDs) in the field and a parti-colored light array (PLA) system in the laboratory under darkroom conditions. BC traps equipped with ultraviolet (UV) LEDs were more attractive to this thrips as compared with blue LEDs. Distances from the point of thrips release to the PLA affected the number of thrips caught independently of trap color.

INTRODUCTION

Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), are among the most important pests attacking a wide variety of plant species including cotton grown in the Western United States (Leigh et al. 1996). Sampling and population monitoring methods are urgently needed in WFT management programs. Ultraviolet (UV) light has been reported to attract many insect species (Hienton 1974). Blue and white colors have been reported to be more attractive to WFT compared with other colors (Beavers et al. 1971, Chang 1990, Cho et al. 1995, Leigh et al. 1996, Mateus and Maxia 1995, Chu et al. 2000, Roditakis et al. 2001, Liu and Chu 2004). Our goal was to develop a trap for field monitoring and potential control of WFT in greenhouse crops. We report here on the results of research to determine the attractiveness of various light sources for the capture of WFT.

MATERIALS AND METHODS

A parti-colored Light Array (PLA) system was arranged in three rows of 10 juxtaposed spaced light source boxes that were stacked vertically against a wall in a (7.9 x 5.2 x 2.7m) (L x W x H) darkroom (Fig. 1). Light source treatments were randomized within two columns of three boxes each. There were five replicates. Each light source was installed in a 25 x 25 x 11cm (L x W x D) plastic box. The inside of each light source box

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was lined with aluminum foil. The front of the box was covered with black cloth with a white fluorescent 9.5 x 9.5cm window area of clear plastic. Each light source box contained one compact light bulb (15 watt, 120V, 60Hz, 750 lumens, Phillips Lighting Co., Somerset, NJ), except for boxes with one UV light bulb (fluorescent black light, BPESL15T, 15W, 120V, 50-60Hz, 200mA, Pico Rivera, CA). Front windows of each light source box were covered with one of five randomly assigned color transparency per replication. The color transparencies obtained from Rosco Roscolux (Stamford, CT) were: #26 Light Red, #10 Medium Yellow, #88 Light Green, #85 Deep Blue, and #00 Clear (used for both white and UV light bulbs). The front of each transparency (9.5 x 9.5cm) was coated with Tanglefoot® Insect Trap Coating (Grand Rapids, MI). Captured WFT were counted on the 8 x 8cm center area of each transparency. Transparencies were held in position on the cover of each light box using magnetic strips on the outside edges of the transparent windows. Spectra of the color transparencies were measured with an ASD-FR spectrometer (Full Range model, Analytical Spectral Devices, Boulder, CO). A halogen light source was directed at a 99% Spectralon panel (Labsphere, Inc., North Sutton, NH) which reflected the light energy to the spectrometer which was positioned perpendicularly to the panel. Transparency spectra were measured by positioning the transparencies about 10cm in front of the light source and recording the spectra. Peak wavelengths were determined by analyzing the spectra from each transparency. The peak wavelengths of the transparencies were: 545nm for #10 Medium Yellow, 650nm for #26 Light Red, 460nm for #85 Deep Blue, and 512nm for #88 Light Green. The peak wavelength of the UV fluorescent light was 369nm. The PLA was powered continuously during the experimental period. Darkroom conditions were 28-30° C and 20-30% RH during the experiment.

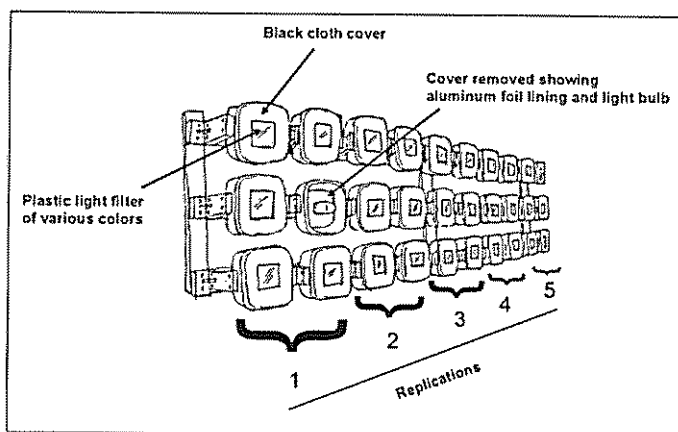


FIG. 1. The parti-colored light array (PLA) system.

LED light lamps used in the studies were 12° 398nm UV LED (L200CUV405-12D, Ledtronics, Inc., Torrance, CA) and 45° 465nm blue LED lamps (Nichia NSPB320BS, Nichia America Corp., Mountville, PA). LED light spectra were measured using the ASD-FR spectrometer by pointing the sensor directly at the LEDs. Peak wavelengths were determined by plotting the spectra from each light source. The LED lamps were fitted on hair clips and energized with 220 ohm resistors *via* a 6V direct current (DC)

adaptor (Radio Shack® Co., Fort Worth, TX, USA) as described elsewhere (Chu et al. 2003). The LED lamps used for Experiments 2 and 3 were connected to a standard 110V alternating current electricity source. For Experiment 4, the LED lamps were connected to a 12V solar/battery operated energizer (Model MAG 12-SP, Parker MacCrory MFG, Co., Kansas City, MO). The energizer was turned on manually at night.

Experiment 1 (WFT attraction to light colors) was conducted in a randomized complete block design. Treatments were six light colors as described earlier. WFT were released at the rate of 1000, 2000 or 3000 for each test 83 or 165cm from the light sources. WFT were collected in sweep nets in an alfalfa, *Medicago sativa* (L.), field at Maricopa, AZ, and released in the darkroom each day for six days. WFT caught over 24h on each Tanglefoot® coated transparencies were counted after each release.

Experiment 2 (WFT catches on LED-BC traps in greenhouse grown alfalfa) was conducted in eight (124 x 60 x 132cm) (L x W x H) wood framed cages (replicates). Cages were covered with 72 mesh plastic screen. Alfalfa cv. CUF 101 was planted in pots (10-15 plants per pot) and six pots were placed in each cage. Treatments were BC traps equipped with blue or UV LED lamps. BC traps without LED were the controls. BC traps (blue Takitrap®, Oecus Ltd., Kimpton, Hertfordshire, England) were 10.0 x 10.5cm in size. The traps were spaced 45cm apart in the cages. Trap bottoms were 3cm above the plant terminals. The plants were 10-15cm high during the experiment. WFT were collected as described earlier and 50 were released in each cage on each day for four weeks from 11 February to 3 March 2004. The LED lamps were illuminated from 1800 to 0700 hours. Traps were retrieved weekly and trap catches were counted. New traps were placed in cages weekly.

Experiment 3 (WFT catches on LED-BC traps in field grown fava bean, *Vicia fava* (L.), was conducted in a randomized complete block design with seven replicates in a fava bean field at Phoenix, AZ. The trap treatments were BC equipped with UV LED or blue LED traps. BC traps not equipped with LED were used as controls. The traps were set 800cm apart along a row. Fava bean rows were spaced 100cm apart, and the plants were spaced about 3cm apart. The plants were about 40-45cm high during the experiment. The traps were mounted vertically on wire stakes. The trap bottoms were about 5cm above the plant tops. Each replicate was set in every other row for seven rows. The traps were retrieved and replaced with new ones daily.

Experiment 4 (WFT catches on LED-BC traps in field grown cotton *Gossypium hirsutum* (L.), was conducted in a randomized complete block design with four replicates in cotton research plots in Holtville, CA. Cotton cv. DPL 5415 was planted and irrigated on 30 March 2004. Standard agronomic practices were followed. Treatments were the same as described for Experiment 3. Traps were retrieved weekly and WFT and bean thrips, *Caliothrips phaseoli* (Hood), catches were counted. New traps were placed in the plots at the same locations during the experimental period from 21 May to 18 June 2004.

The numbers of WFT and bean thrips caught were analyzed using ANOVA. The means were separated using Tukey's test at $P = 0.05$ (Anonymous 1994).

RESULTS AND DISCUSSION

Overwhelmingly more WFT were attracted to 369nm wavelength UV (black) fluorescent light in Experiment 1 (WFT attraction to light colors) compared with white, red (650nm), medium yellow (545nm), light green (512nm), and deep blue (460nm) colors under the darkroom experiment (Table 1).

In Experiments 2 and 3 (WFT catches on LED-BC traps in greenhouse grown alfalfa and in field grown fava bean), mean numbers of WFT caught on 398nm UV LED-BC traps were greater compared with 465nm blue LED-BC traps (Tables 2 and 3). For both experiments, Blue LED-BC traps caught more WFT compared with BC controls.

TABLE 1. Mean Thrips (\pm SE) Numbers of *Frankliniella occidentalis* (Pergrande) Caught per Colored Light Source When Releases Were Made at Distances of 83 and 165 Centimeter Distances from the Six Different Light Sources in a Darkroom.

Light color	Mean numbers/trap/24 h after release		
	No. thrips released		
	1000	2000	3000
83cm from light source			
UV	82.6 \pm 25.5a ^a	148.0 \pm 27.2a	221.4 \pm 52.2a
Blue	1.8 \pm 0.6b	4.8 \pm 1.3b	5.2 \pm 3.5b
Green	1.8 \pm 0.6b	2.0 \pm 0.9b	3.4 \pm 1.7b
Yellow	1.2 \pm 0.6b	1.4 \pm 0.2b	1.8 \pm 0.7b
Red	1.2 \pm 0.6b	2.0 \pm 0.7b	2.0 \pm 0.9b
Clear	4.0 \pm 1.7b	3.6 \pm 1.2b	6.6 \pm 1.4b
F, prob.	9.9, <0.001	28.3, <0.001	17.2, <0.001
165 cm from light source			
UV	9.2 \pm 2.9a	32.8 \pm 11.5a	40.8 \pm 2.2a
Blue	0.8 \pm 0.6b	0.8 \pm 0.6b	0.4 \pm 0.4b
Green	0.2 \pm 0.2b	0.8 \pm 0.2b	1.0 \pm 0.8b
Yellow	0.2 \pm 0.2b	0.2 \pm 0.2b	0.8 \pm 0.8b
Red	0.2 \pm 0.2b	1.6 \pm 0.7b	1.2 \pm 0.4b
Clear	0.8 \pm 0.6b	1.8 \pm 1.6b	6.4 \pm 2.9b
F, prob.	8.0, <0.001	7.5, <0.001	102.3, <0.001

^a Means in a column not followed by the same letter are significantly different by Tukey's HSD, $P = 0.05$, $df = 5, 30$.

TABLE 2. Mean (\pm SE) Numbers of *Frankliniella occidentalis* (Pergrande) Caught on Blue Sticky Card Traps With or Without LEDs from Alfalfa in a Greenhouse, 2004.

LED type	No./trap/week				
	11 Feb	18 Feb	25 Feb	3 March	Mean
UV	4.1 \pm 0.9a ^a	4.6 \pm 0.4a	5.9 \pm 0.2a	7.6 \pm 0.4a	5.6 \pm 0.3a
Blue	3.1 \pm 0.6ab	3.9 \pm 0.6a	4.3 \pm 0.4b	6.8 \pm 0.5a	4.5 \pm 0.4b
Control ^b	1.1 \pm 0.2b	1.1 \pm 0.2b	1.5 \pm 0.2b	2.8 \pm 0.3b	1.6 \pm 0.1c
F, prob.	7.3, <0.007	76.1, <0.001	177.7, <0.001	63.5, <0.001	88.9, <0.001

^a Means in a column not followed by the same letter are significantly different by Tukey's HSD, $P = 0.05$, $df = 2, 14$.

^b No LED.

TABLE 3. Mean (\pm SE) Numbers of *Frankliniella occidentalis* (Pergrande) Caught on Blue Sticky Card Traps With or Without LEDs in a Fava Bean Field, Phoenix, AZ, 2004.

LED type	No./trap/day				
	12 March	16 March	17 March	18 March	Mean
UV	22.0 \pm 2.2a ^a	33.7 \pm 4.8a	29.6 \pm 3.5a	22.6 \pm 3.0a	27.5 \pm 1.5a
Blue	20.8 \pm 3.5a	31.0 \pm 2.4a	25.4 \pm 3.3a	17.4 \pm 2.8a	23.9 \pm 1.5b
Control ^b	14.5 \pm 4.7b	20.9 \pm 1.2b	14.7 \pm 4.6b	6.1 \pm 1.7b	14.5 \pm 1.2c
F, prob.	7.4, <0.006	4.6, <0.024	6.7, <0.007	10.6, <0.001	52.9, <0.001

^a Means in a column not followed by the same letter are significantly different by Tukey's HSD, $P = 0.05$, $df = 2, 12$.

^b No LED.

Mean numbers of WFT and bean thrips caught on 465nm blue LED-BC traps in Experiment 4 (WFT catches on LED-BC traps in field grown cotton) were greater compared with 398nm UV LED-BC traps (Table 4).

TABLE 4. Mean (\pm SE) Numbers of *Frankliniella occidentalis* (Pergrande) and *Caliothrips phaseoli* (Hood) Caught on Blue Sticky Card Traps in a Cotton Field in Holtville, CA, 2004.

Light color	No. /trap/week				
	21 May	28 May	4 June	11 June	Mean
<i>F. occidentalis</i>					
UV LED	539.5 \pm 47.6b ^a	410.8 \pm 49.2ab	433.2 \pm 46.4b	324.3 \pm 12.8b	427.0 \pm 20.1b
Blue LED	858.7 \pm 45.5a	505.7 \pm 46.0a	539.2 \pm 39.4a	604.2 \pm 36.8a	626.9 \pm 31.4a
Control ^b	524.0 \pm 27.2b	328.2 \pm 53.7b	360.3 \pm 56.8b	277.8 \pm 13.4b	372.6 \pm 23.8b
<i>F. prob.</i>	23.0, <0.001	13.4, <0.002	12.3, <0.002	90.8, <0.001	60.5, <0.001
<i>C. phaseoli</i>					
UV LED	16.0 \pm 2.5a	23.7 \pm 3.9b	17.0 \pm 2.8b	14.5 \pm 1.8ab	17.8 \pm 2.1b
Blue LED	17.3 \pm 1.4a	41.0 \pm 5.3a	34.0 \pm 4.8a	21.5 \pm 3.2a	28.5 \pm 3.0a
Control ^b	14.2 \pm 1.8a	25.8 \pm 5.3ab	19.3 \pm 3.2b	10.8 \pm 1.1b	17.5 \pm 2.2b
<i>F. prob.</i>	0.7, <0.544	5.1, <0.030	9.5, <0.005	8.5, <0.010	8.3, <0.008

^aMeans in a column not followed by the same letter are significantly different by Tukey's HSD, $P = 0.05$, $df = 2, 10$.

^bNo LED.

Reasons for the differences in trap catches between 398nm UV LED- and 465nm blue LED-BC traps in field grown fava bean in Phoenix, AZ, and cotton in Holtville, CA, are not known, but may be due to higher WFT population in cotton. More WFT were caught in traps placed 83cm from the PLA compared with 165cm from the light source (Table 1). Catches of WFT at 369nm UV light sources ranged from 21 to 111 times more compared with numbers caught at any other light source at 83cm distance and 6-464 times at 165cm distance. These results suggest that WFT response to light occurs over short distances.

Thrips orientation to colors may be compounded under field conditions compared with their behavior in darkroom. Stavisky et al. (2002) found UV reflective mulch reduced *Frankliniella* spp. densities by 45% and tomato spotted wilt incidence by 50%, suggesting that UV reflectance-induced color changes in plant canopy adversely affected *Frankliniella* spp. landing on the hosts. Other research indicates that 290-320nm UVB is related to the trophic-level interactions between algae density and the density of predator larval chironomid tubes (Diptera: Chironomidae) (Bothwell et al. 1994). Bean thrips herbivory is reduced by UVB radiation (Mazza et al. 1999) suggesting changes in leaf chemistry (Warren 2002) under field conditions that interact with the plant pests.

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